



# Ford Inova Fairfax Hospital CIREN Team

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*Ford Motor Company*

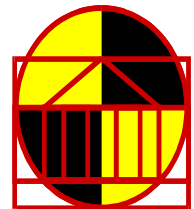
Inova  
Regional  
Trauma  
Center



DEPARTMENT OF MECHANICAL  
AND AEROSPACE ENGINEERING



UVA Center  
For Applied  
Biomechanics



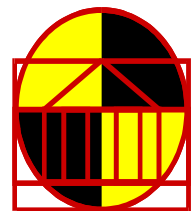
# The Use of MADYMO to Elucidate Injury Mechanisms in a Complex, Multiple-Impact Collision

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University of Virginia

Samir Fakhry, Dorraine Watts, David Bean  
INOVA Fairfax CIREN



UVA Center  
For Applied  
Biomechanics



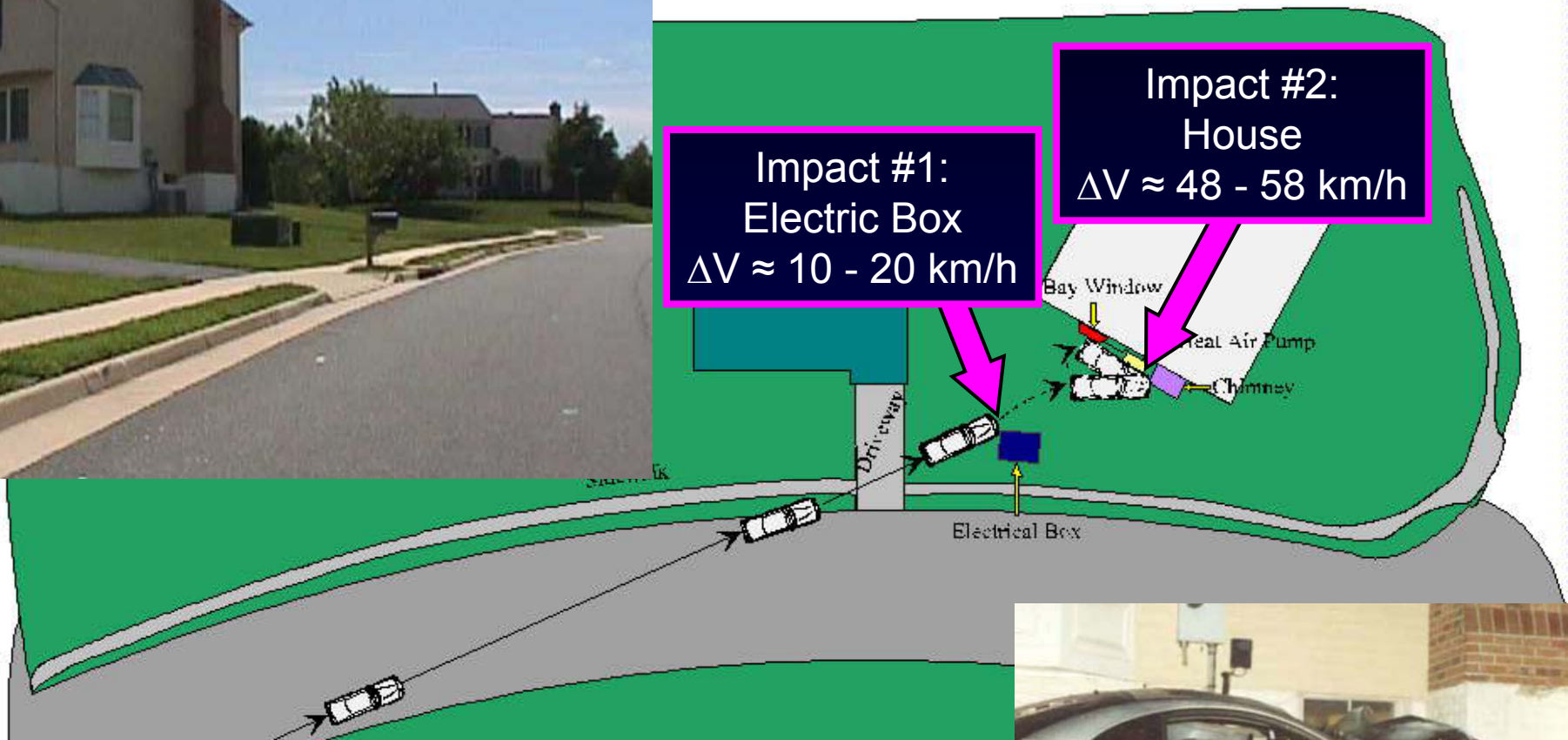
Injuries (ICD)	AIS Severity	Info Source	Aspect (R,L,bilat,etc)	Contact Area (door, seat,etc)	Mechanism (direct,etc)	Confid. Level	Rank
Multifocal subarachnoid hemorrhages (852.00)	140684.3	Autopsy	Whole				
Scalp laceration– occipital (873.0)	190602.1	Autopsy	Posterior				
Facial abrasions (cheek) (910.0)	290202.1	Autopsy	Bilateral				
Neck contusion (920)	390402.1	Autopsy	Left				
Lung contusion (920)	441410.4	Autopsy	Bilateral				
Lung laceration w hemothorax (861.21)	441414.3	Autopsy	Right				
Heart rupture (861.03)	441014.6	Autopsy	Center				
Radius fracture (813.83)	752802.2	X-ray	Right				
Ulna fracture (813.83)	753202.2						
Wrist avulsion (881.12)	790700.1	Autopsy	Right				
Upper extremity abrasions (912.0)	790202.1	Autopsy	Bilateral				
Tibia fracture (823.92)	853405.3	Autopsy	Right				
Fibula fracture (823.92)	851606.2	Autopsy	Right				

# Crash Overview



Impact #1:  
Electric Box  
 $\Delta V \approx 10 - 20 \text{ km/h}$

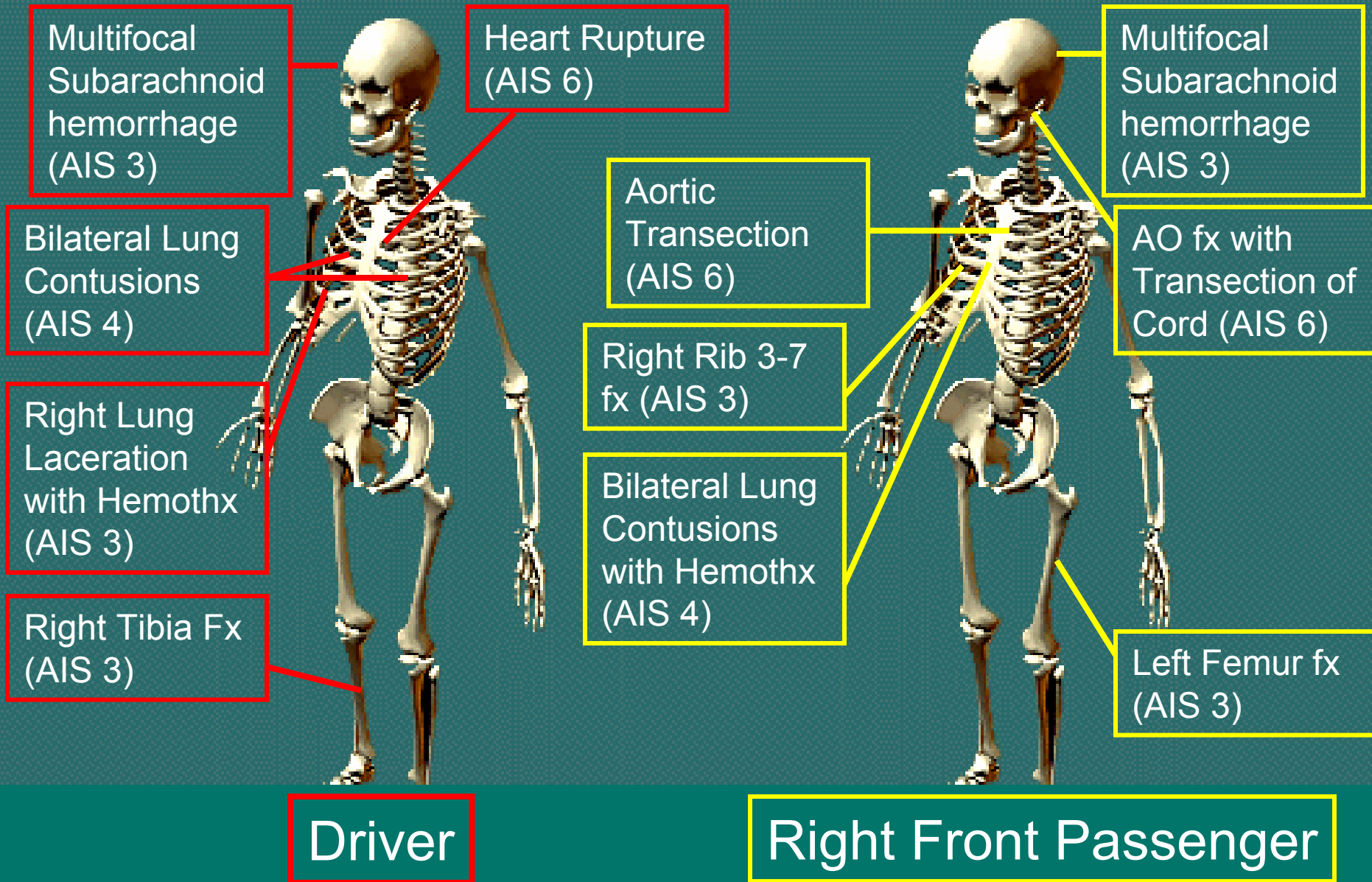
Impact #2:  
House  
 $\Delta V \approx 48 - 58 \text{ km/h}$



2001 Mitsubishi Eclipse Coupe  
Unbelted 18 y/o male driver (BAC 0.17)  
Unbelted 19 y/o male right-front passenger (BAC 0.10)  
2:30 AM, 82 mph in a 25 mph zone



# Injury Outcome (AIS 3+ only)

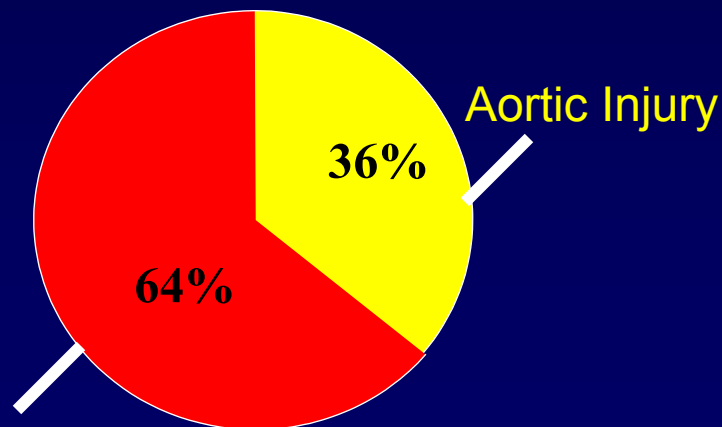




# Research Questions

- When did the airbags deploy?
- What is the primary mechanism of injury?
  - Airbag?

OOPS Driver Fatalities  
(64% Thoracic MAIS)

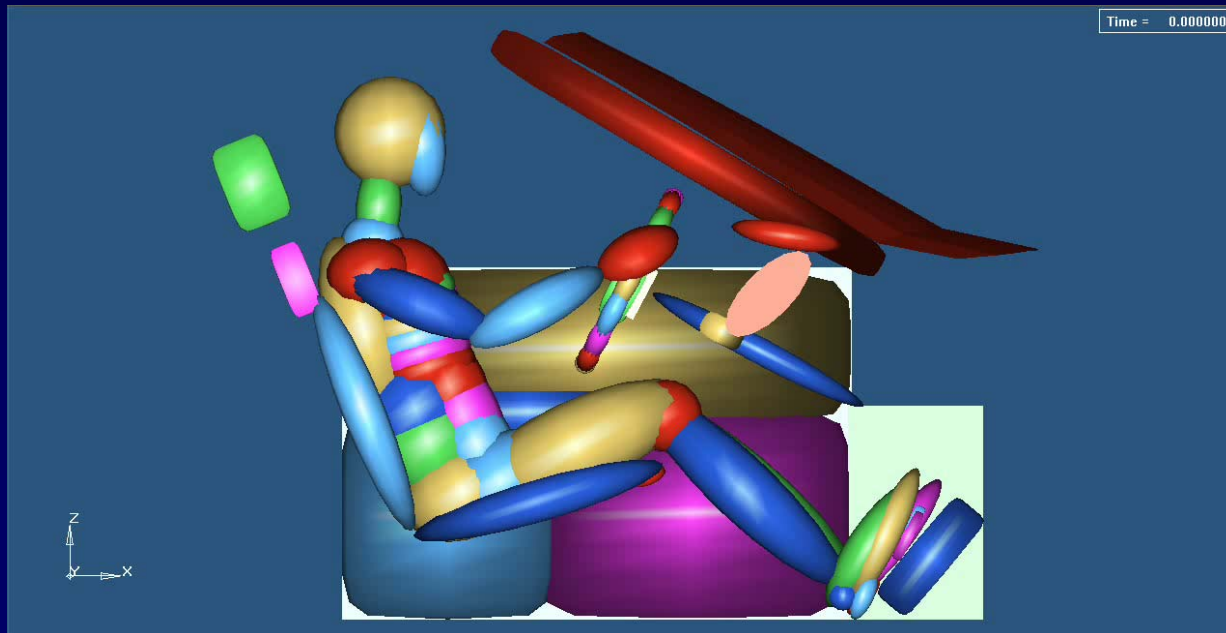


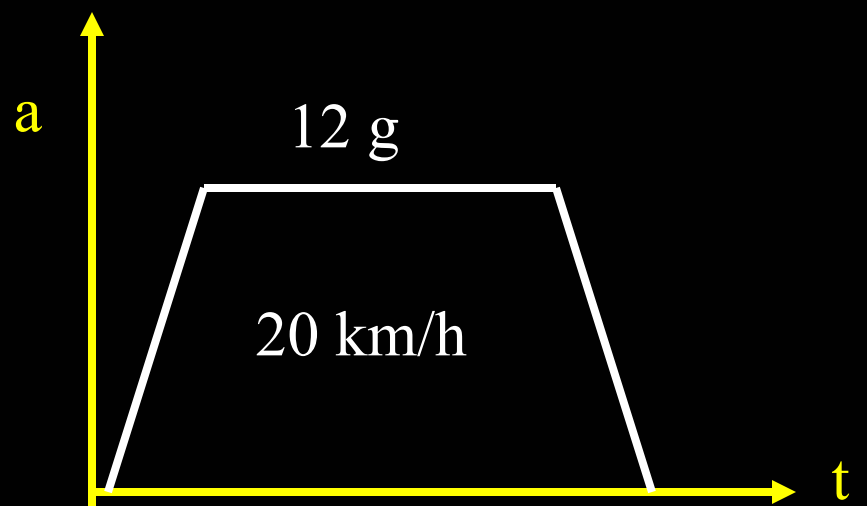
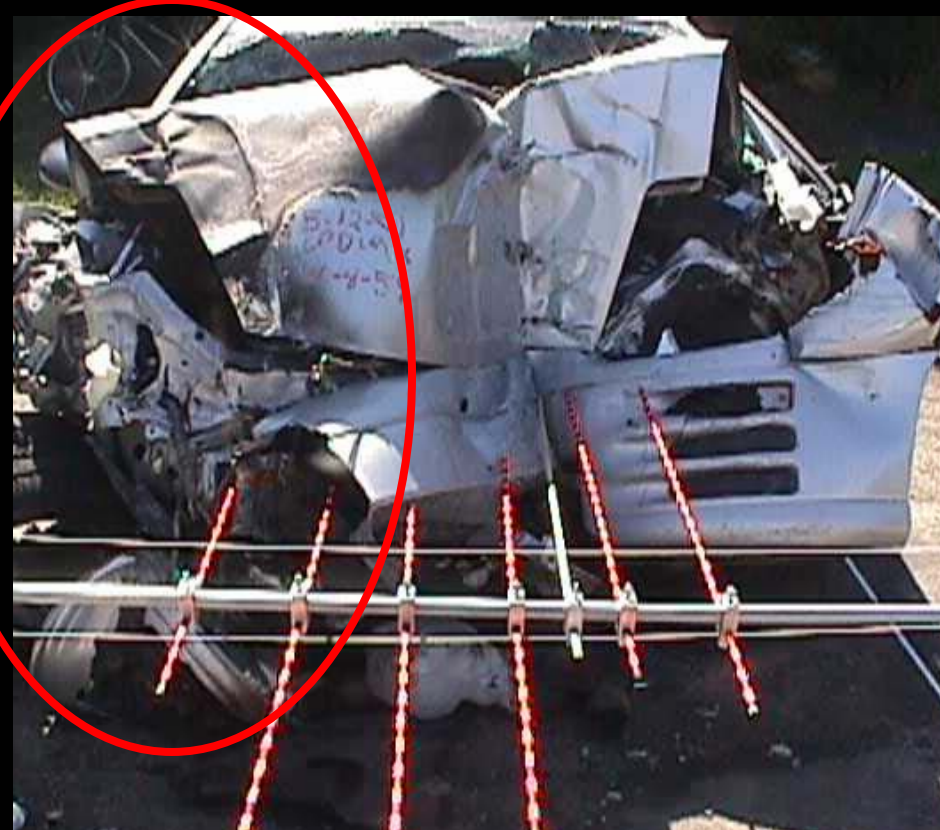
Other (e.g., Heart Lacerations,  
Cardiac Tamponade, Hemo/Pneumothx)



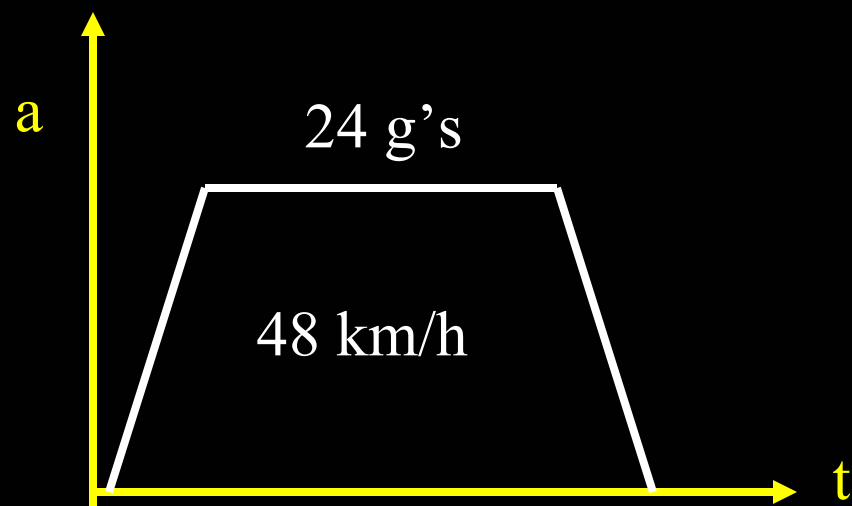
# Model Description

- MADYMO 6.0
- Multibody ellipsoid Hybrid III 50<sup>th</sup> male
- Finite element airbag (Generic, “depowered”)
- Small vehicle ellipsoidal model with deforming steering column



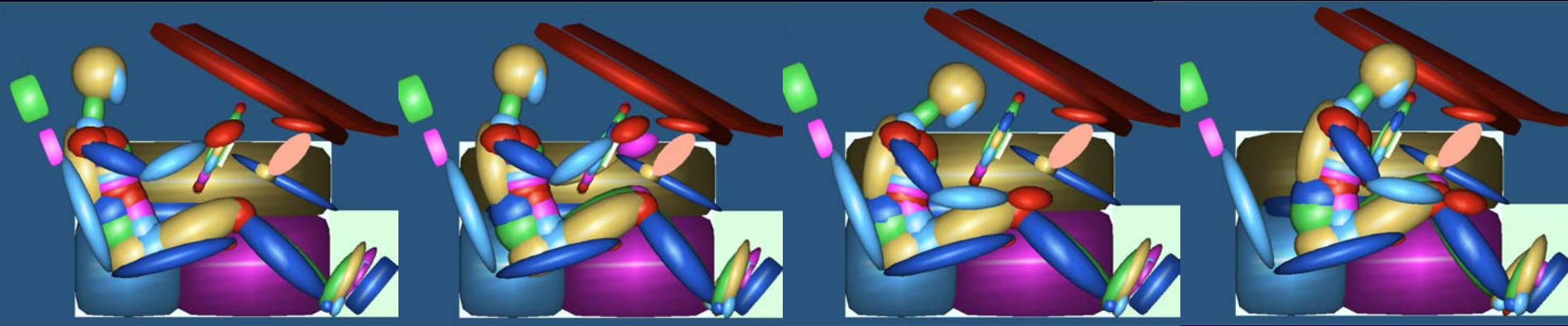




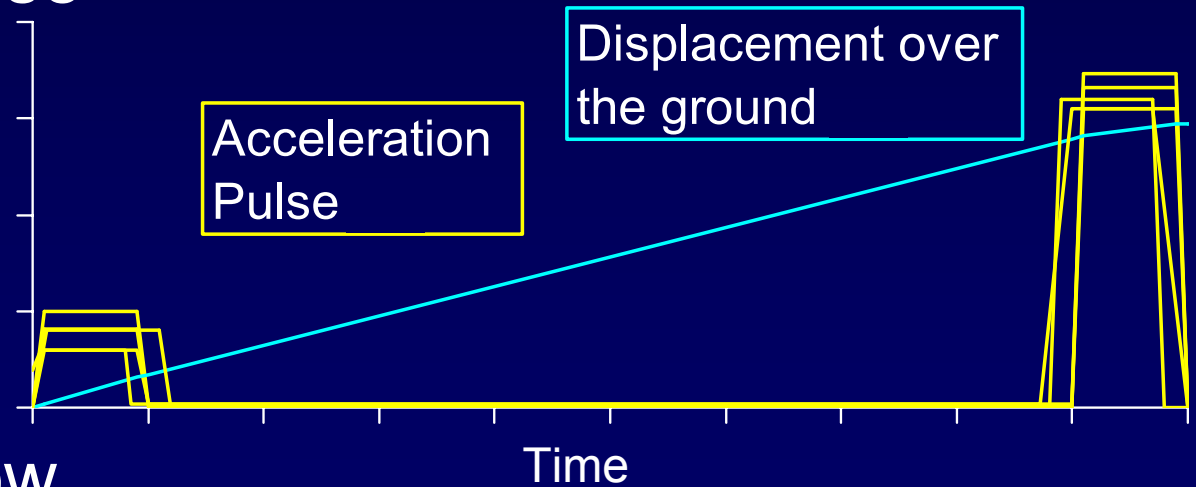


# Modeling Strategy – Sensitivity Study

- Initial Occupant Position



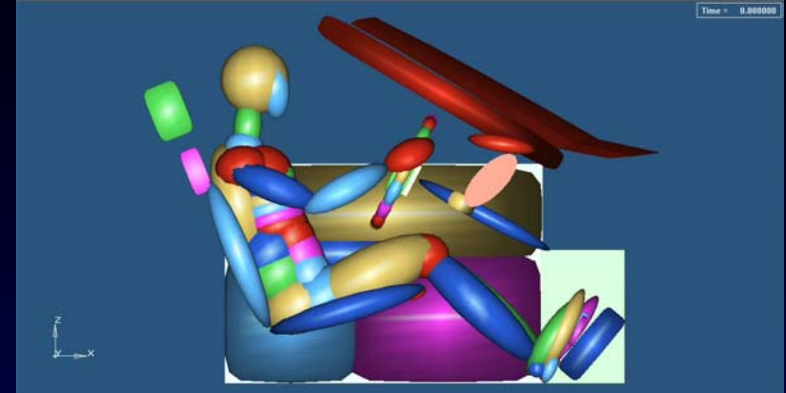
- Acceleration Pulse



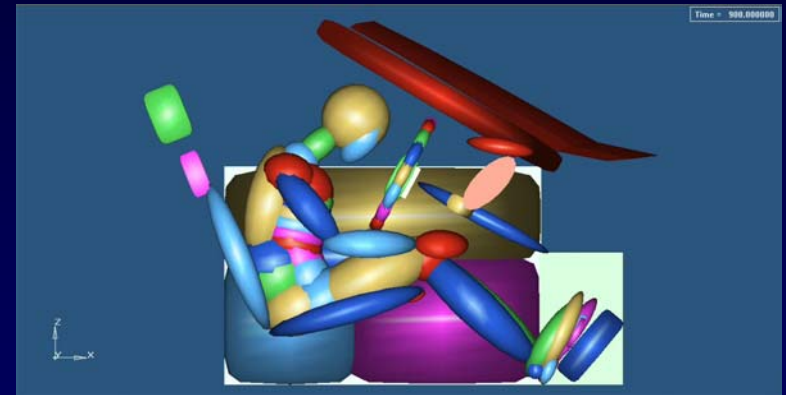
- Airbag Mass Flow

# Crash/Injury Scenarios

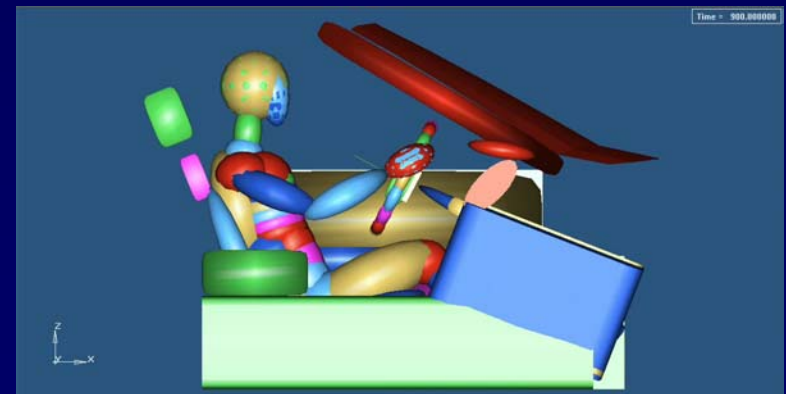
1. Airbag deployed in first collision, deflated for second collision



2. Airbag deployed in second collision, occupant OOP from first collision



3. Airbag deployed in second collision, but occupant not OOP



# Thoracic Injury Criteria

Compression Criterion



Acceleration  
Criteria



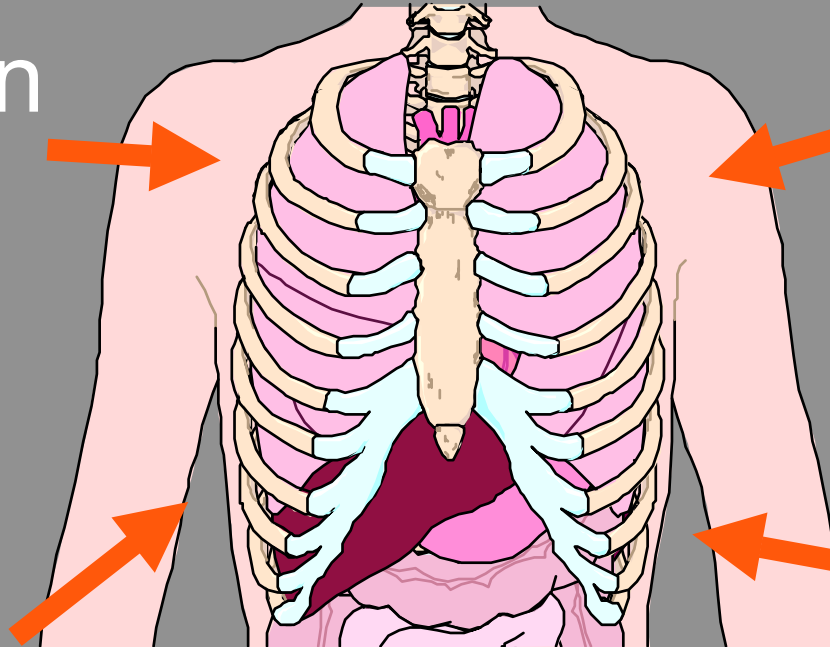
Velocity  
Threshold



Force  
Criterion



Viscous  
Criterion





# Thoracic Response and Injury



# Chest Compression

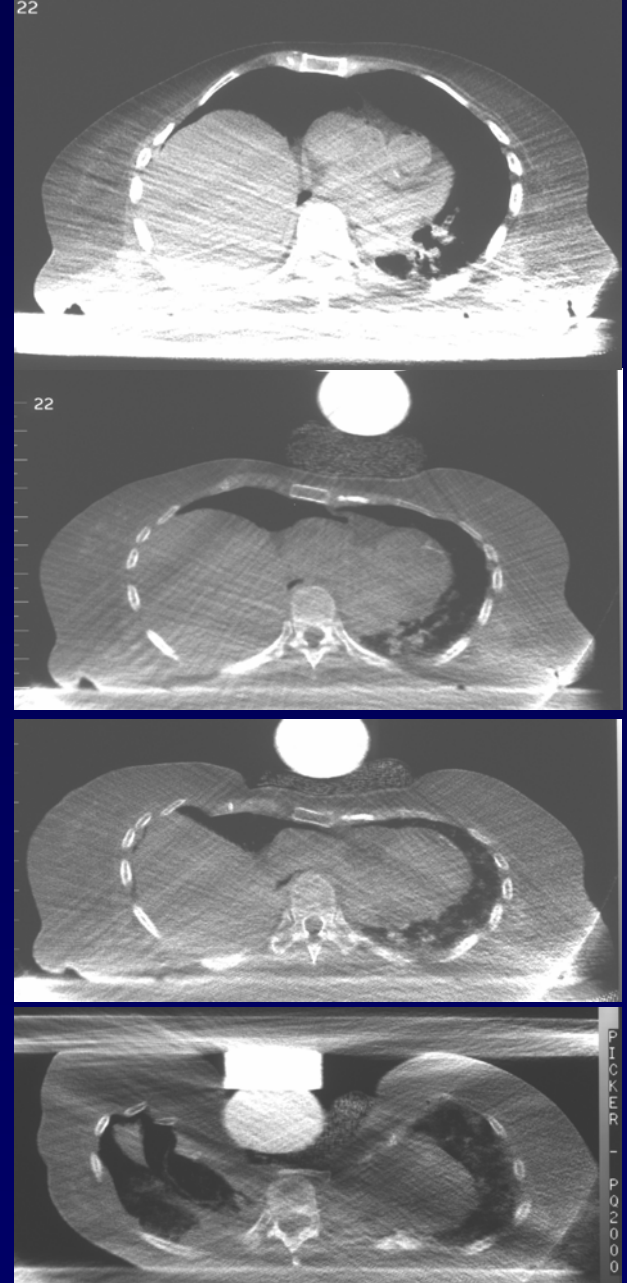
0% Compression

Onset of rib fractures (~20%)

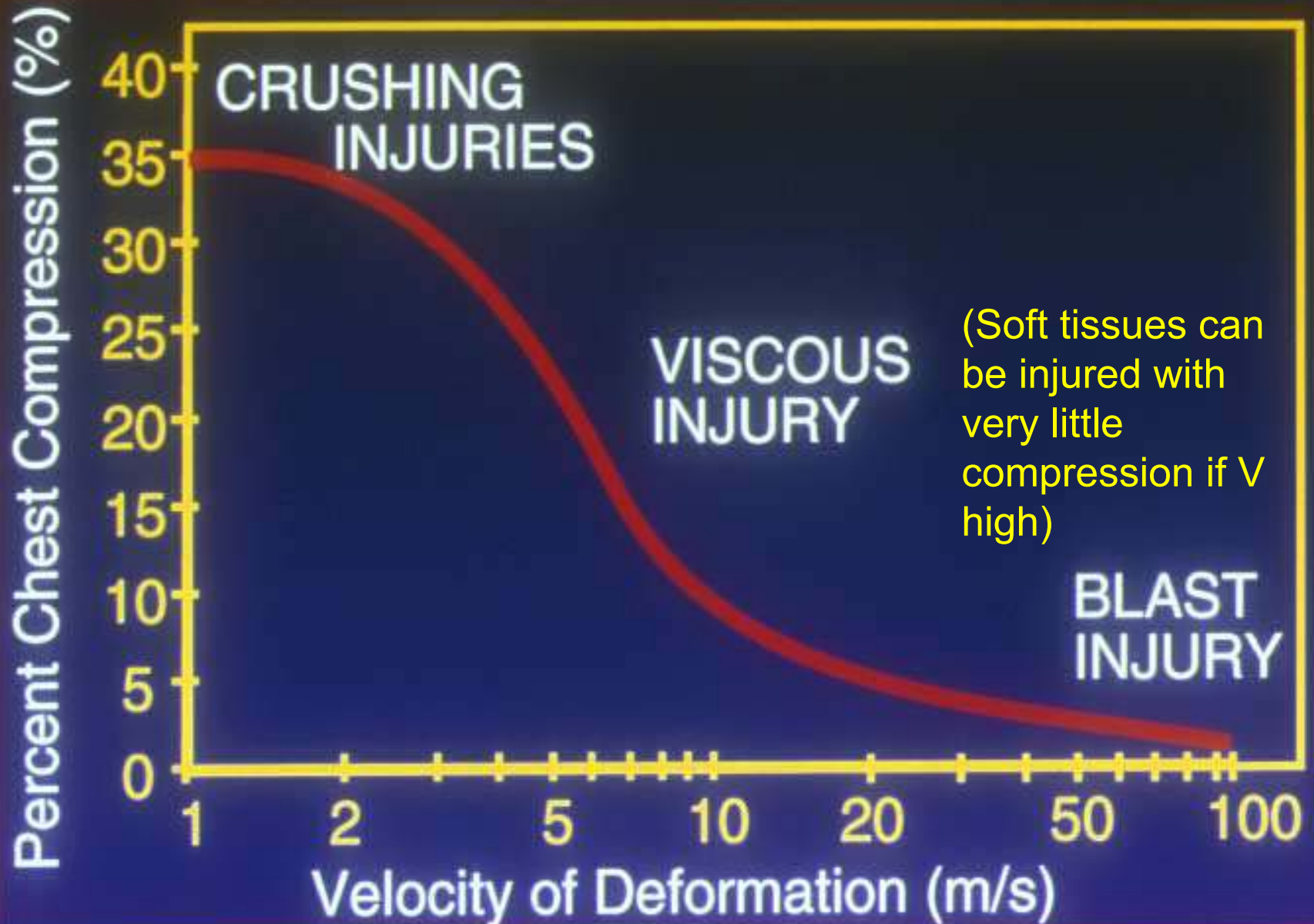
Flail chest/organ crush (~40%)

Sternum contacts spine (~60%)

Cmax good predictor of organ injury at rates below 3 m/s

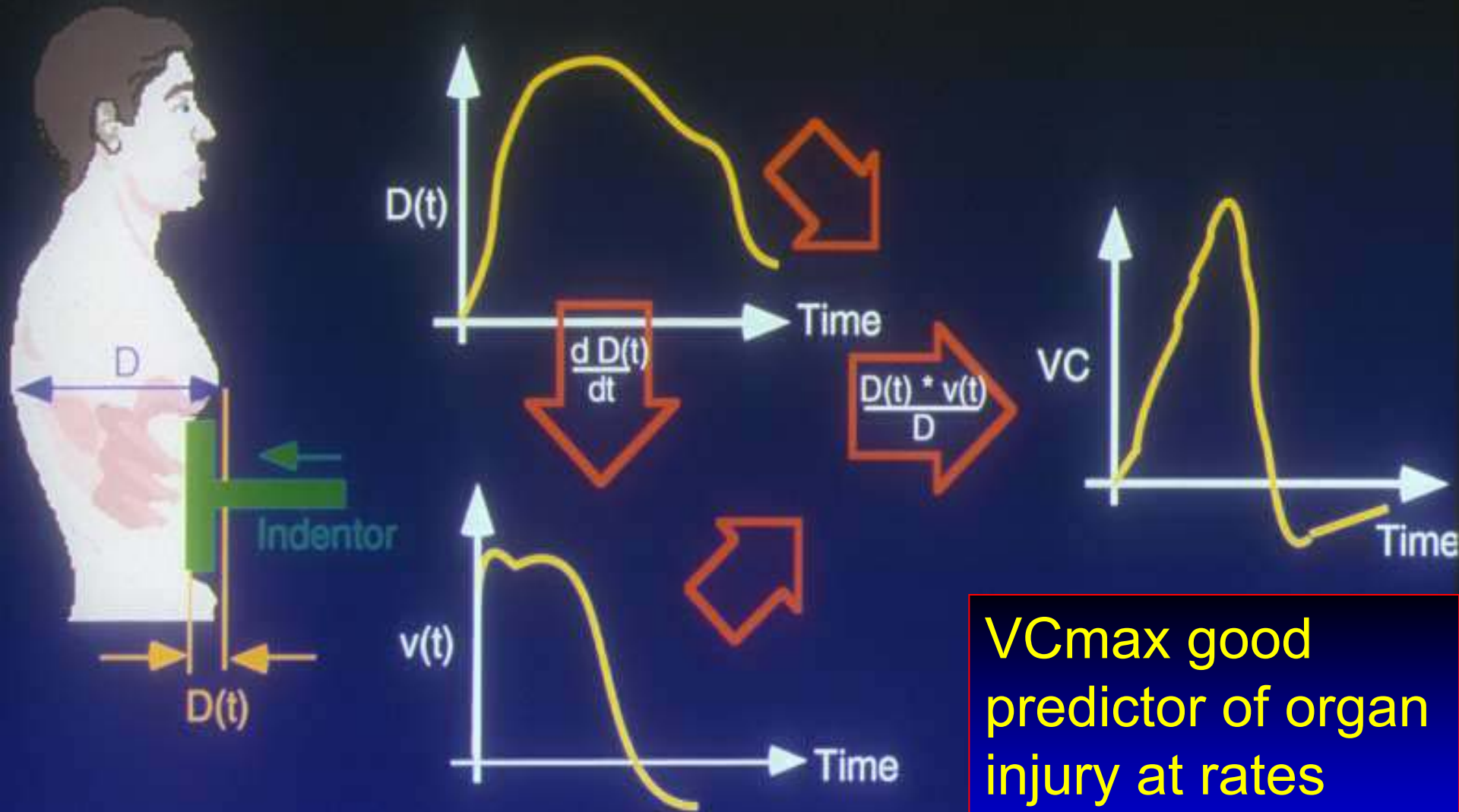


# Thoracic Injuries





# Viscous Criterion, VCmax



VCmax good predictor of organ injury at rates above 3 m/s



# Thoracic Injury Criteria

Compression Criterion



Acceleration  
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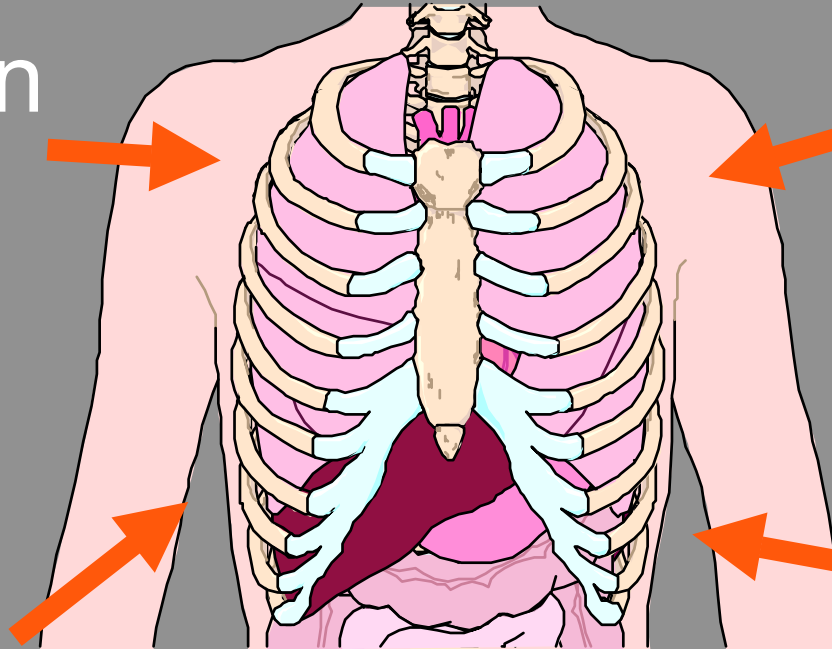
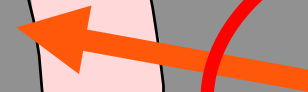
Velocity  
Threshold



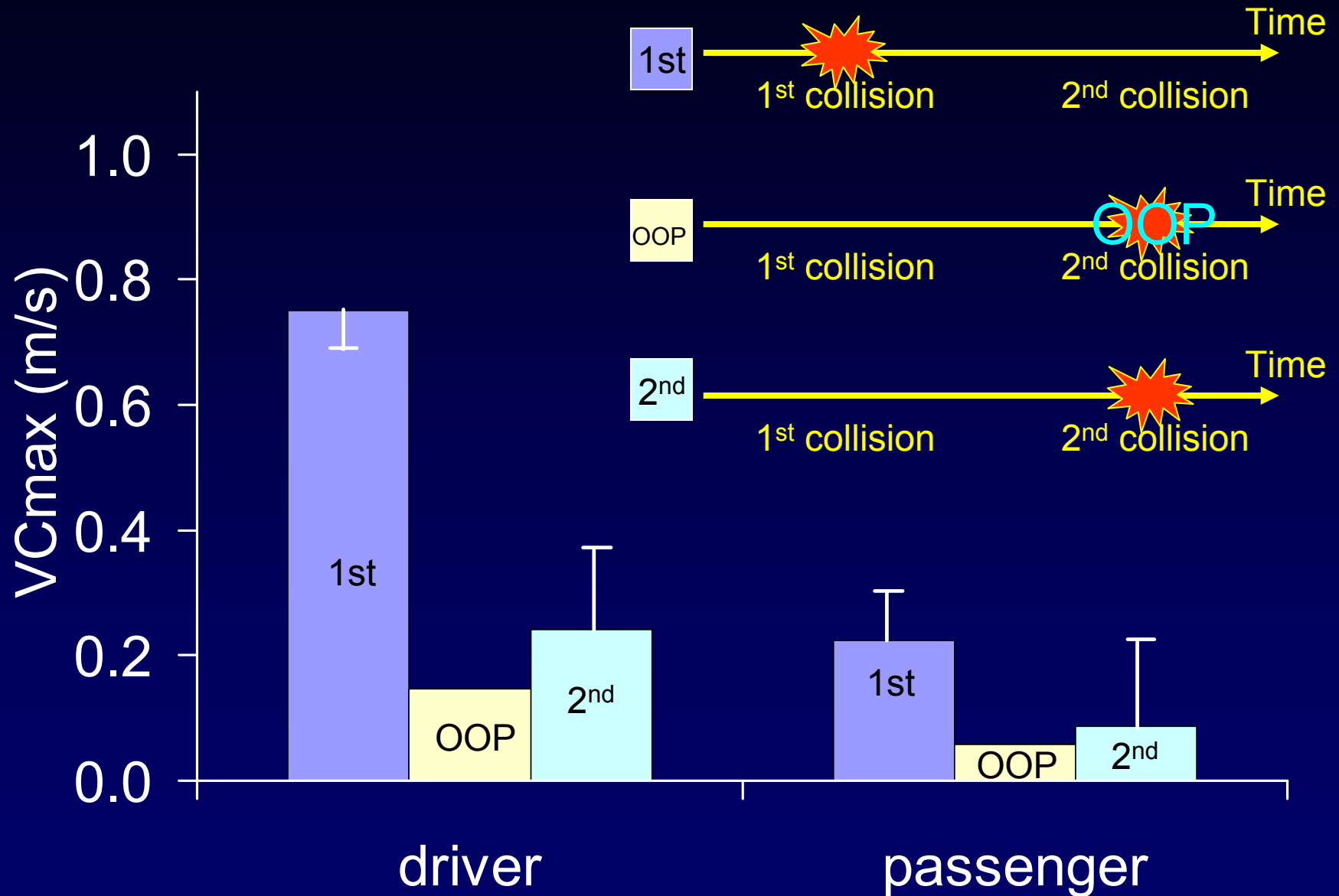
Force  
Criterion



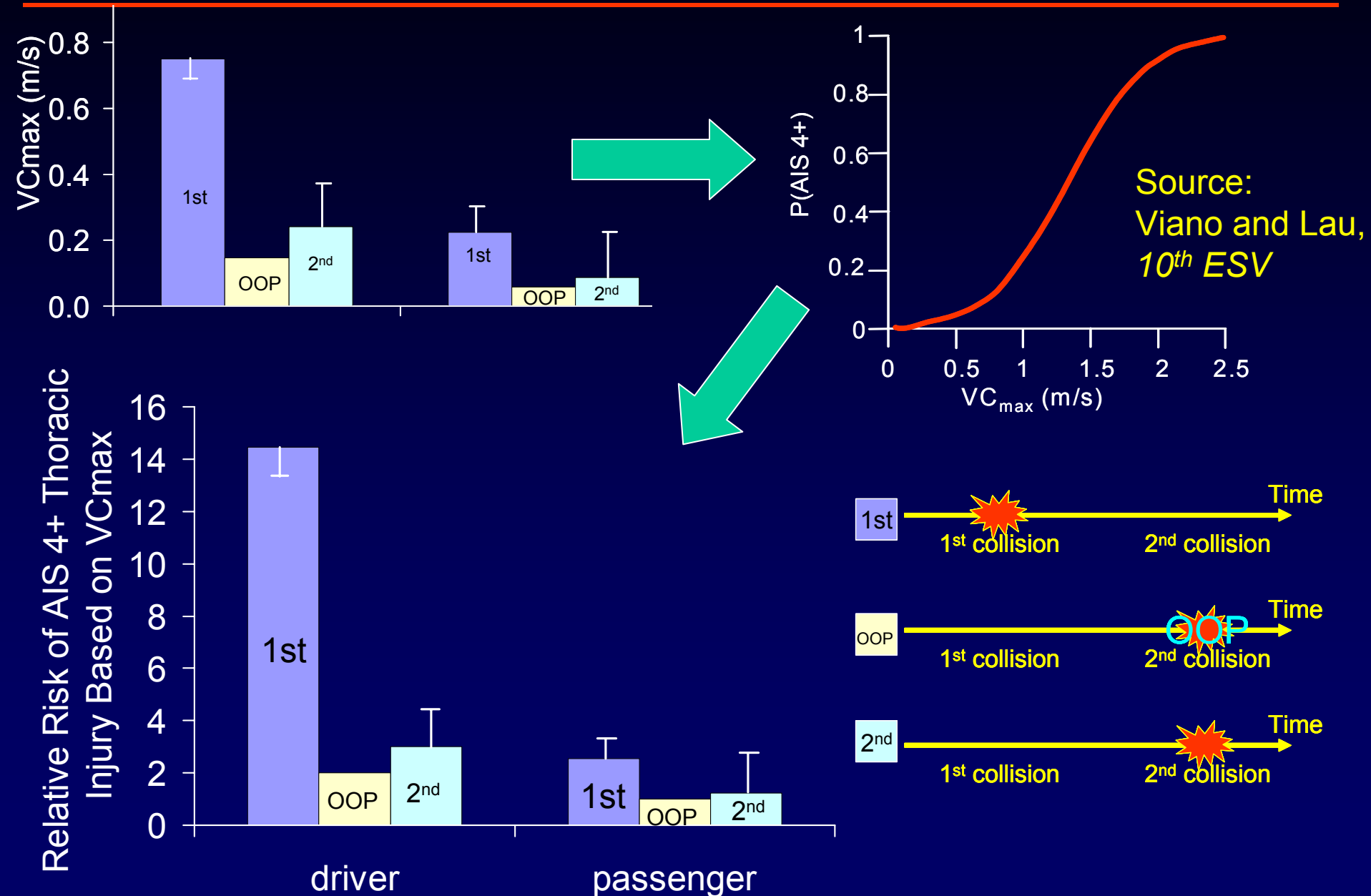
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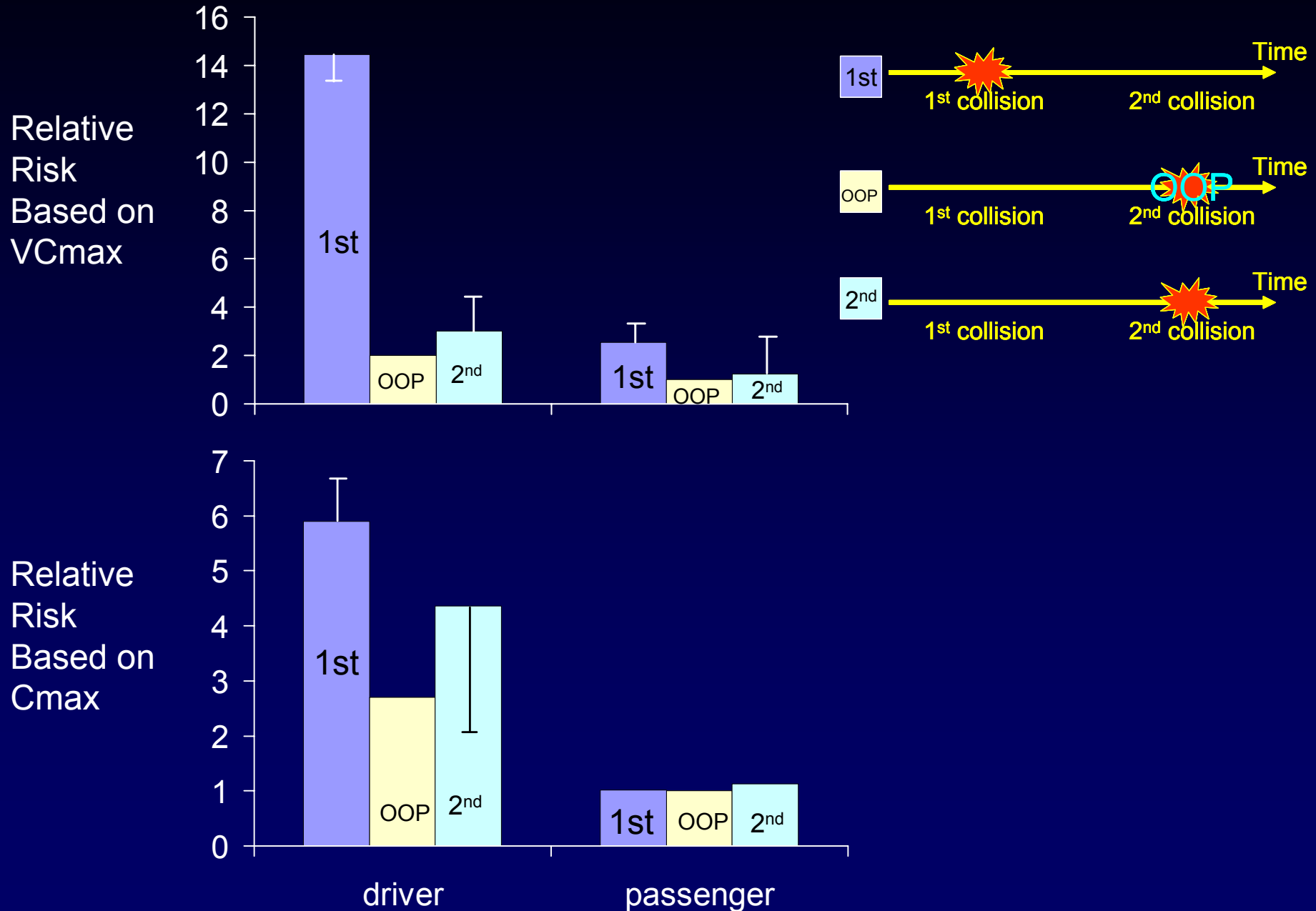
# Results – Viscous Thoracic Injury



# Interpretation – Viscous Criterion

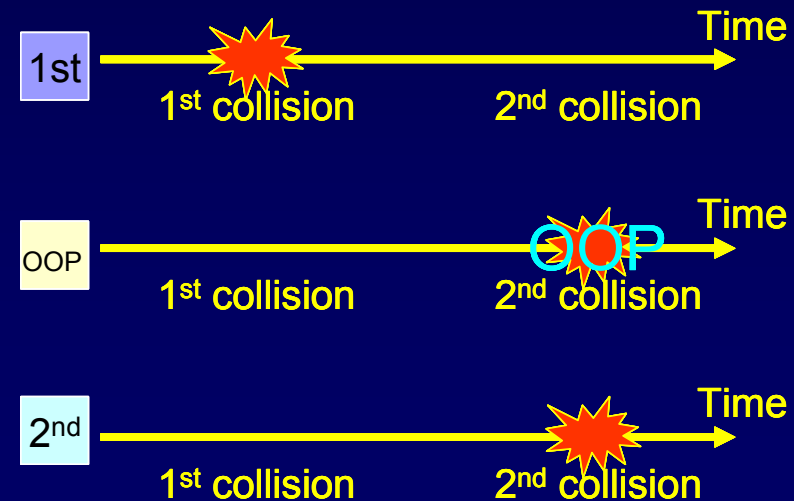
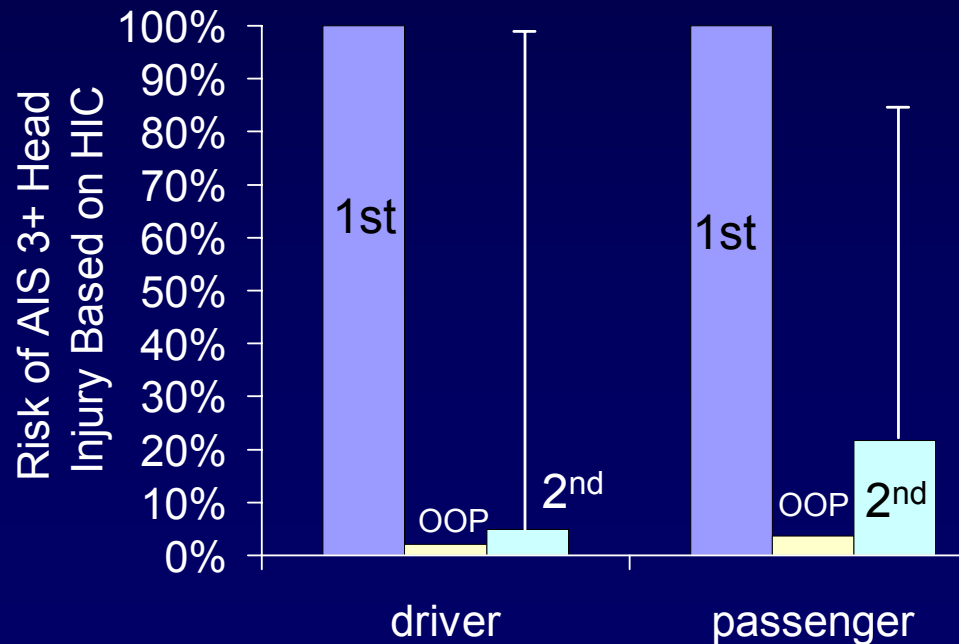
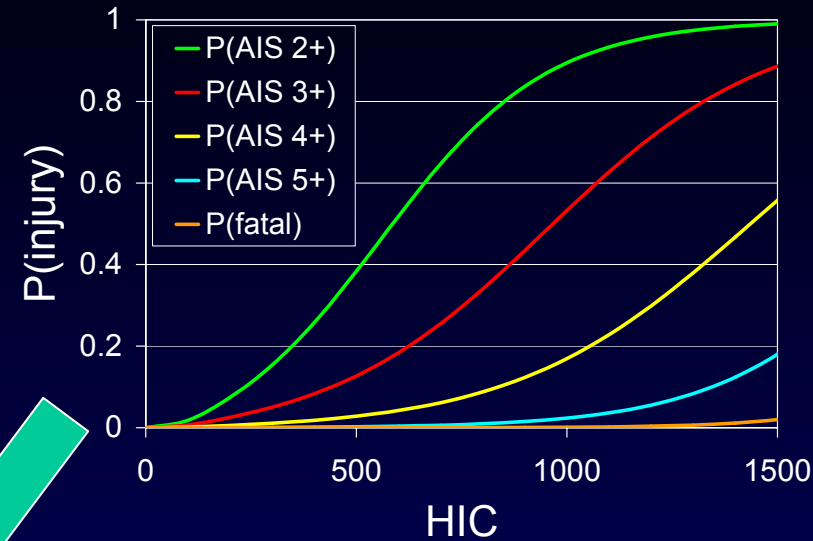
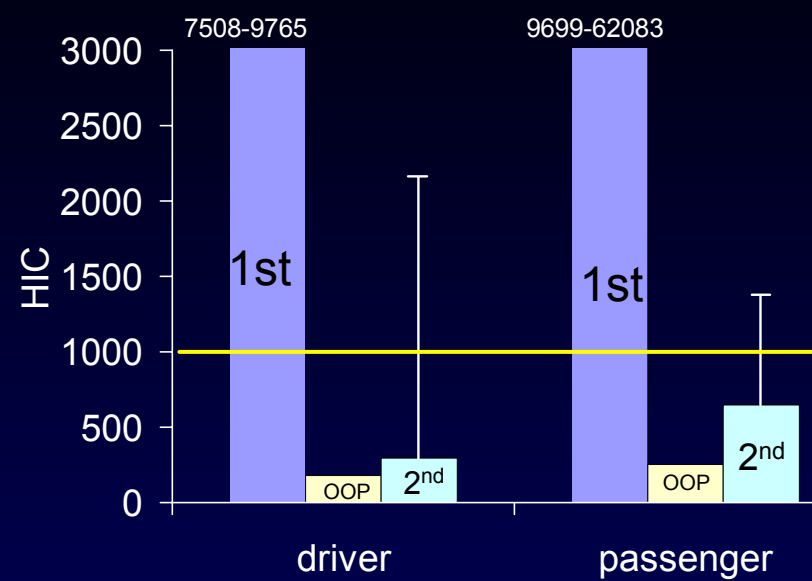


# Interpretation of Injury Measures – Relative Risk

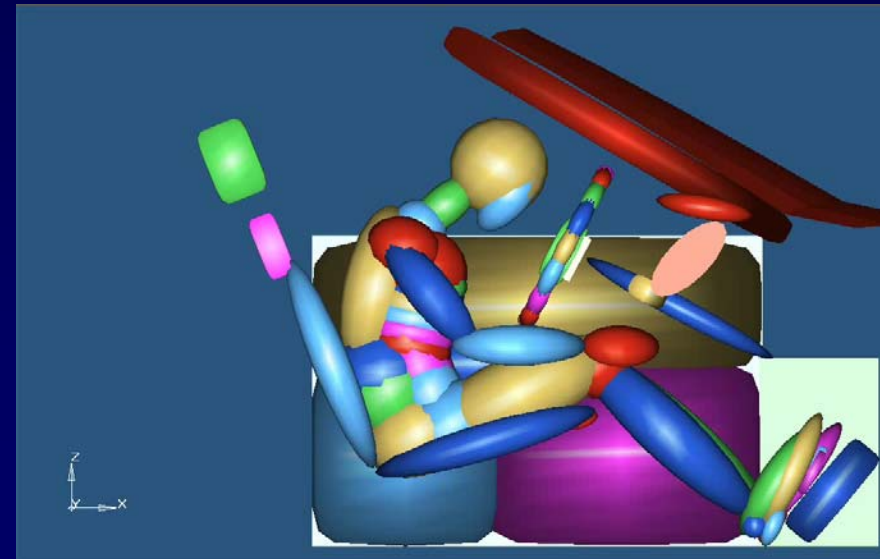
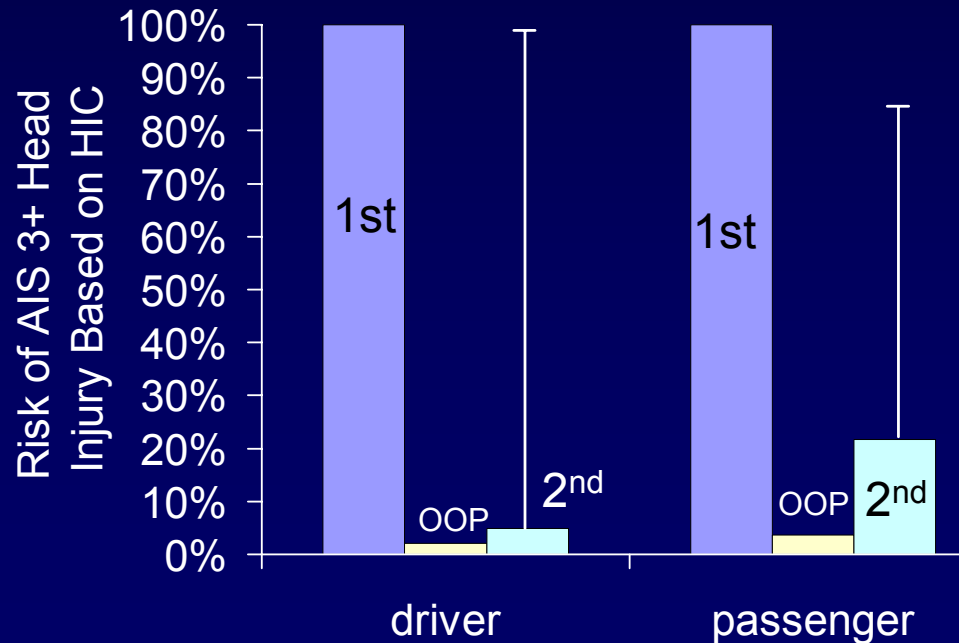
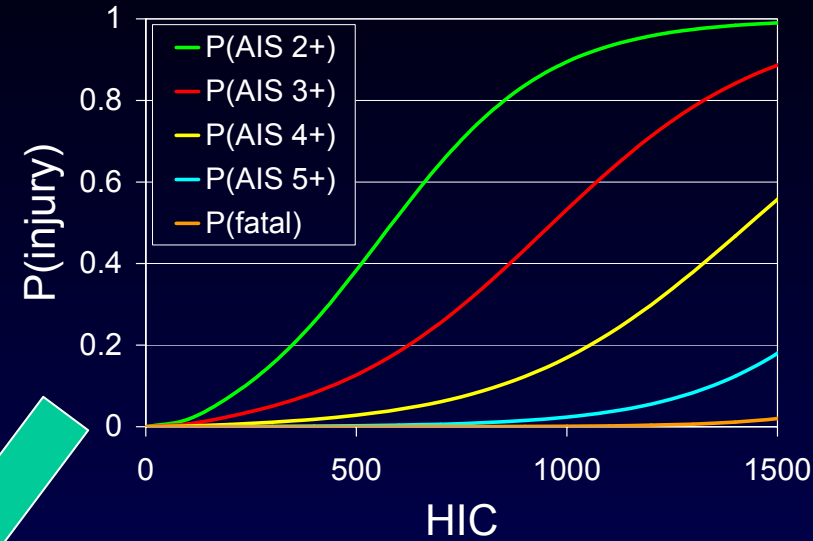
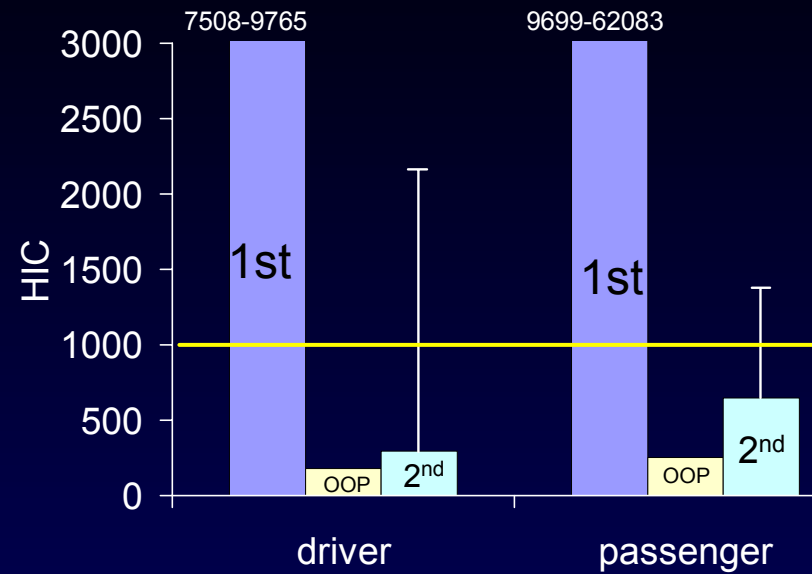




# Interpretation of Head Injury Measures

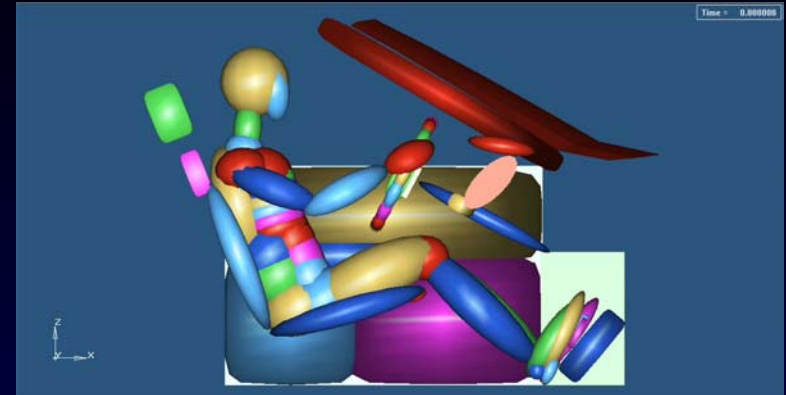


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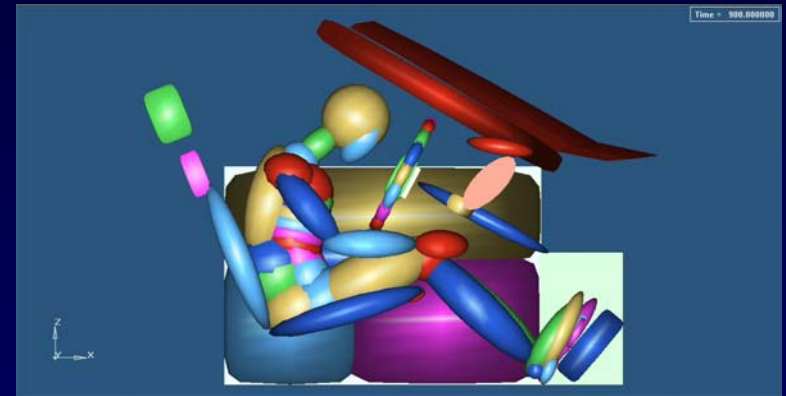


# Crash/Injury Scenarios

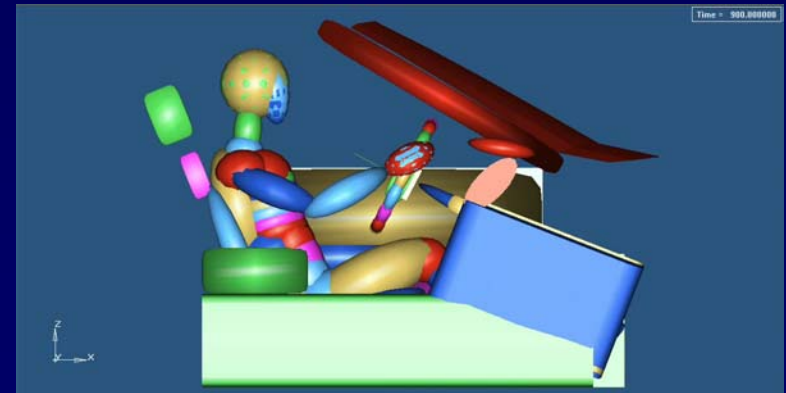
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# Crash/Injury Scenarios

1. Airbag deployed in first collision

**Most Likely Scenario**



2. Airbag deployed in second collision

**Driver: 3 to 12 Times Lower Injury Risk than Scenario 1**



3. Airbag deployed in first collision, but occupant OOP

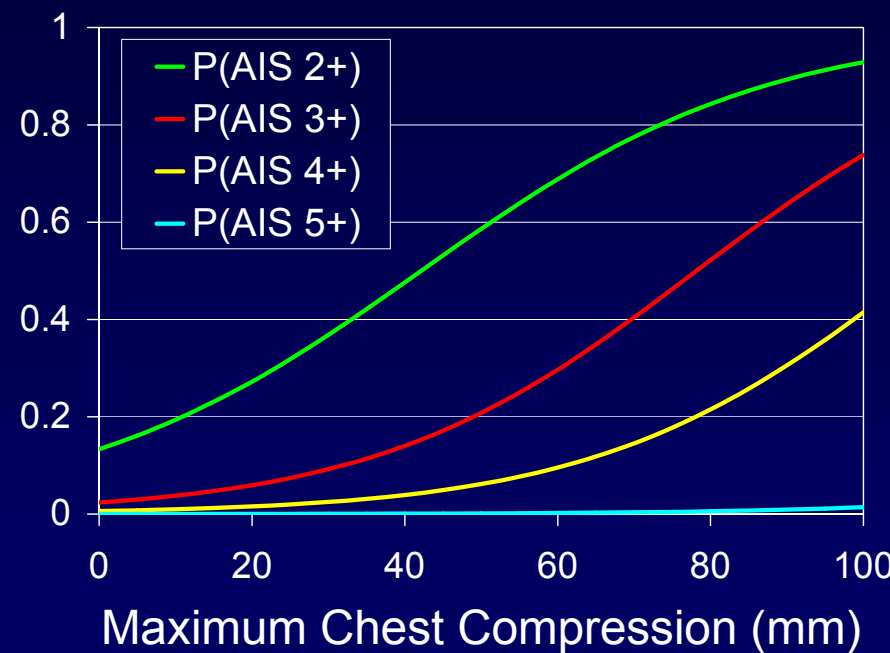
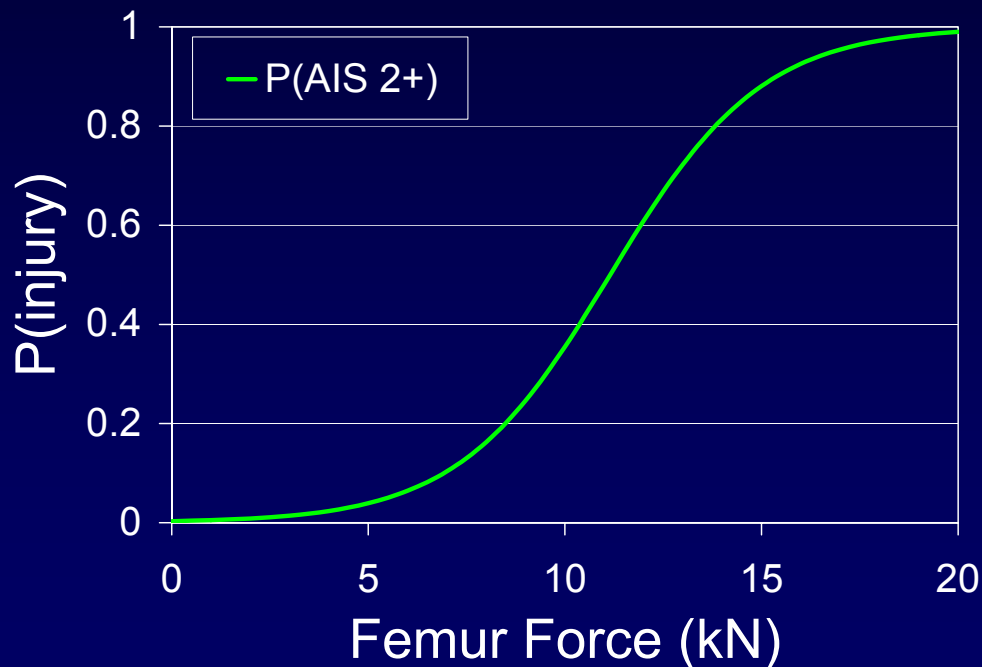




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# Conclusions and Caveats

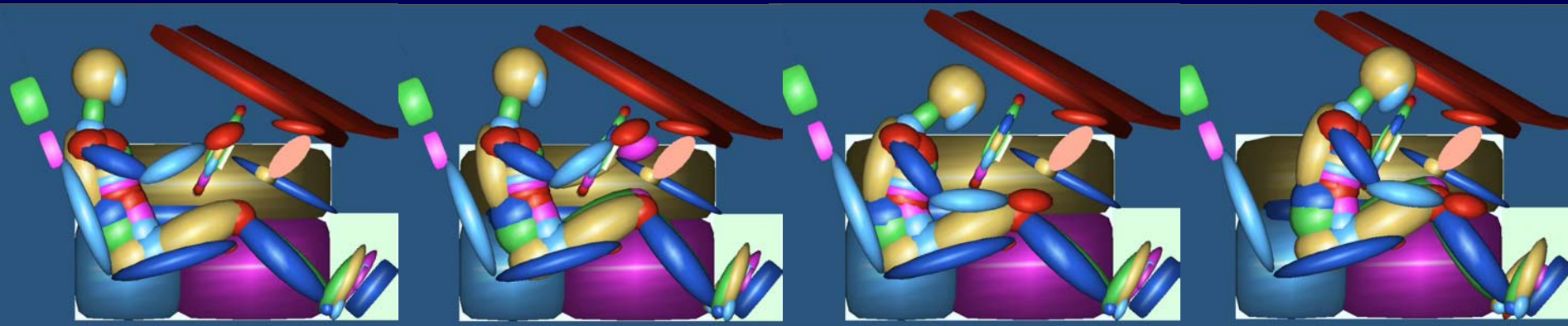
- Tool Useful to Aid Understanding of Crash and Injury Causation
  - Injury Risk Functions Can Provide some Quantitative Assessment of Relative Risks



# Conclusions and Caveats

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- Sensitivity Must be Considered
  - Occupant Position, Acceleration Pulse, Direction of Collision Vector, Collision Speed, Airbag Mass Flow, Steering Column Stiffness



# Conclusions and Caveats

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  - Injury Risk Functions Can Provide some Quantitative Assessment of Relative Risks
- Sensitivity Must be Considered
  - Occupant Position, Acceleration Pulse, Direction of Collision Vector, Collision Speed, Airbag Mass Flow, Steering Column Stiffness
- All Tools Have Limitations
  - Dummy  $\neq$  Human
  - Applicability of computer modeling is limited in virtually all real world crash scenarios
  - Impossible to eliminate every possible scenario



# Limitations of Dummies (Physical or Computational)



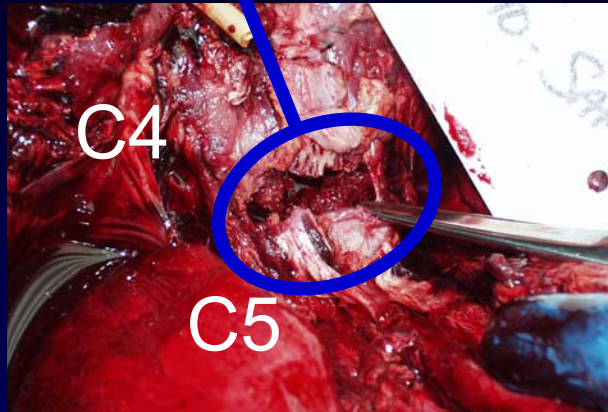


# Limitations of Dummies

- Dummy
  - Chest deflection low
  - Neck forces low
  - HIC low
  - Femur forces low
  - **No Injury**
- Similar-size cadaver?

# Autopsy Results from Cadaver Test

Dislocated Cervical Spine  
Fx. (AIS 5)



Femoral Neck Fx. (AIS 3)



23 Rib Fx.  
Bilaterally (AIS 4)  
Sternal Fx. (AIS 2)

# Conclusions and Caveats

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- Tool Useful to Aid Understanding of Crash and Injury Causation
  - Injury Risk Functions Can Provide some Quantitative Assessment of Relative Risks
- Sensitivity Must be Considered
  - Occupant Position, Acceleration Pulse, Direction of Collision Vector, Collision Speed, Airbag Mass Flow, Steering Column Stiffness
- Simulations Only a Tool
  - Must be interpreted very carefully
  - Applicability of computer modeling is limited in virtually all real world crash scenarios
  - Impossible to eliminate every possible scenario